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Title: ACTUATED SIGNALS IN TRANSIMS

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Actuated Signals in TRANSIMS

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Los Alamos National Laboratory
12 January 2000*

Abstract

This presentation outlines recent work implementing and calibrating actuated traffic controls and vehicle detectors in TRANSIMS. We have developed a generic control that provides a flexible approach to representing such devices. Although not modeled upon specific existing hardware or algorithms, our implementation provides a responsive control over a wide variety of demand conditions.

Outline

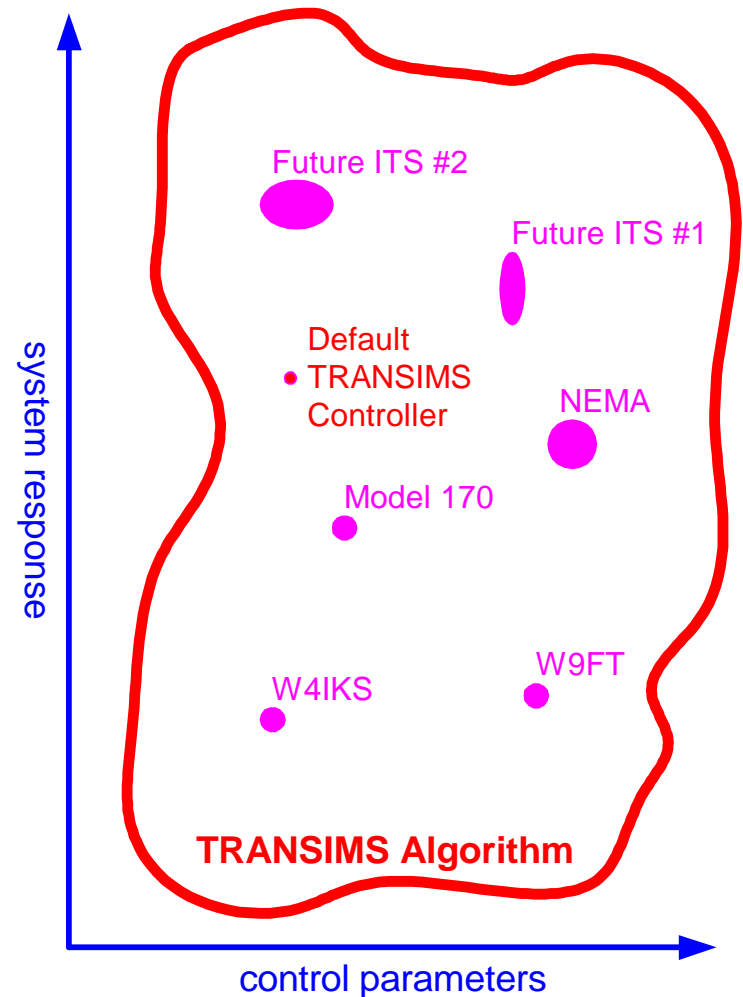
- *motivation*
- *approach*
- *implementation*
 - *network representation*
 - *signal properties*
 - *detector properties*
- *calibration*
- *applications*
- *prospects*

Motivation

- It is *difficult and expensive to gather information* about existing signal and detector configurations.
 - For example, the Portland, Oregon region has *several thousand signals* spread over a dozen jurisdictions: different controllers are used, data formats vary, and some data does not exist in digital format.
- It is *hard to forecast* signalization for future-year planning studies.
- Many *different types* of signal controllers exist.
- ITS-based controllers will have *capabilities beyond current technology*.

Approach

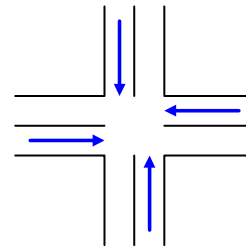
- *Focus on the properties of generic, flexible, all-purpose controllers and detectors.*
- *Avoid implementing numerous, specific, existing and future signal controllers/detectors.*
 - *This can be done when the need arises, however.*
- *Explore the controller- and detector-parameter space for information on performance of actual and future systems.*
- **GOAL:** *Build a controller that works well where data on actual controls cannot be easily obtained.*



Implementation

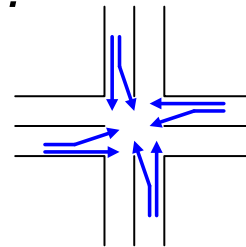
■ *TRANSIMS already models . . .*

- *unsignalized intersections*
- *pre-timed controls*
- *phase relationships*
- *uncoordinated signals*
- *coordination of signals*



■ *Current work focuses on . . .*

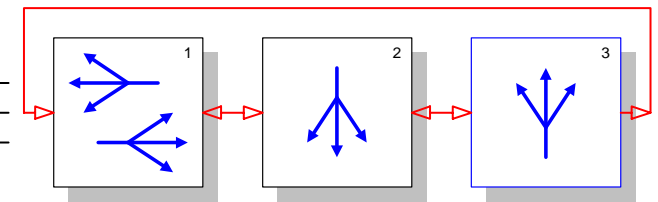
- *actuated signals*
- *generic control algorithm*
- *detectors*



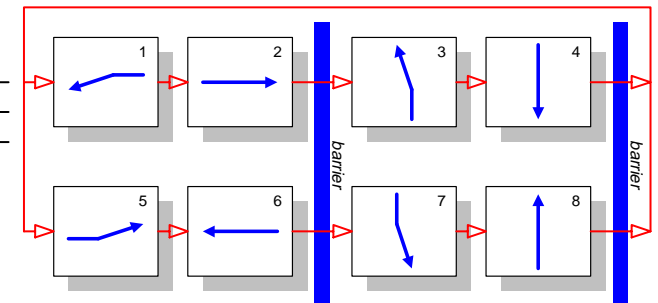
■ *Future work will involve . . .*

- *more complex ring structures*
- *algorithms for specific controllers*
- *wide-area control*
- *ITS technologies*

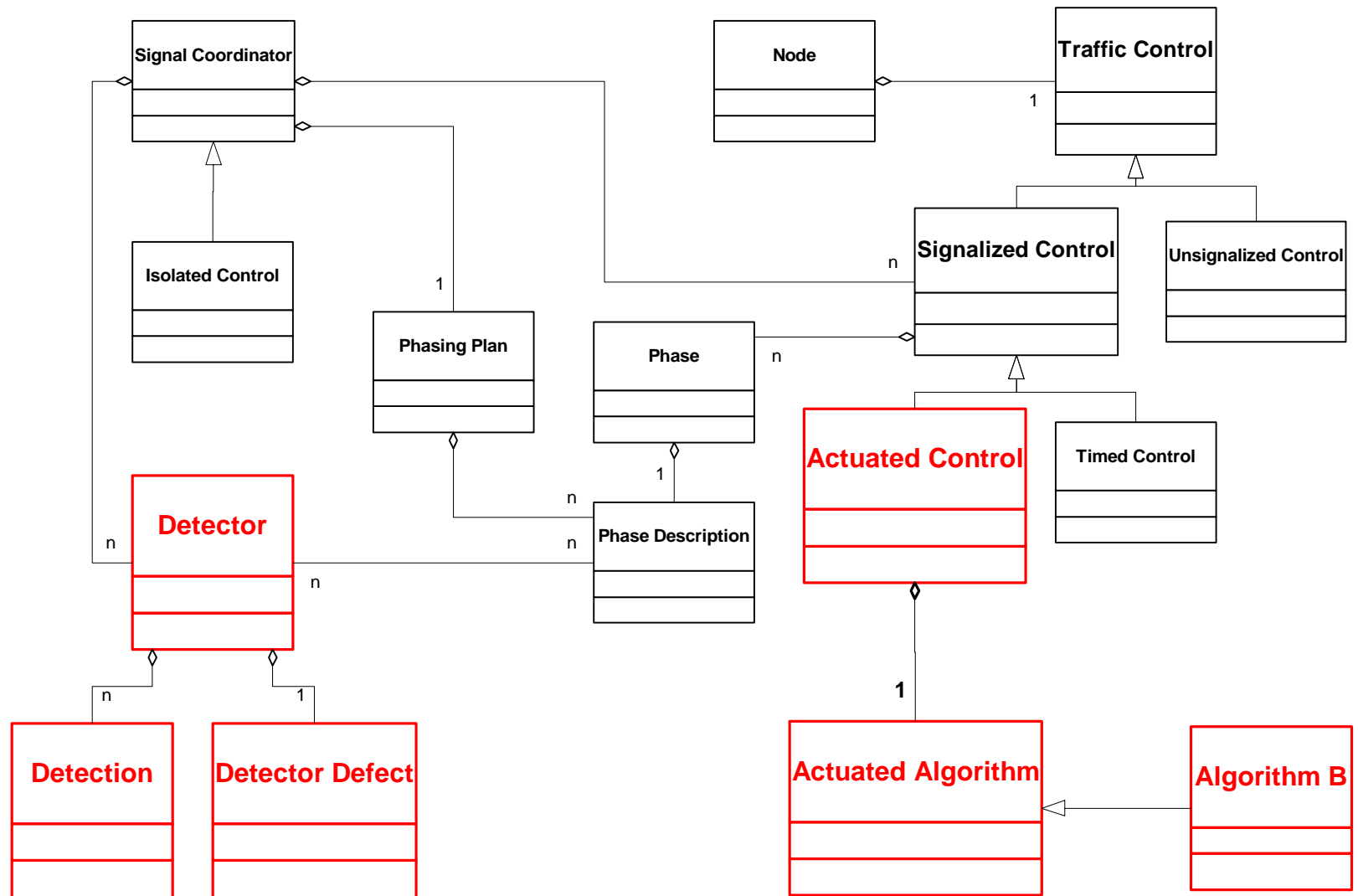
Single-Ring Controller



Dual-Ring Controller

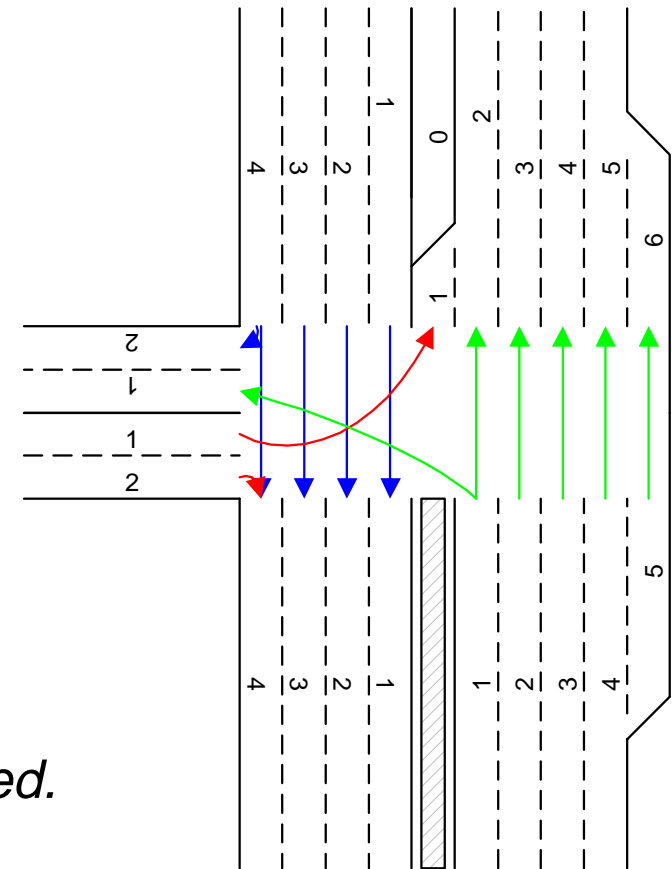


Framework



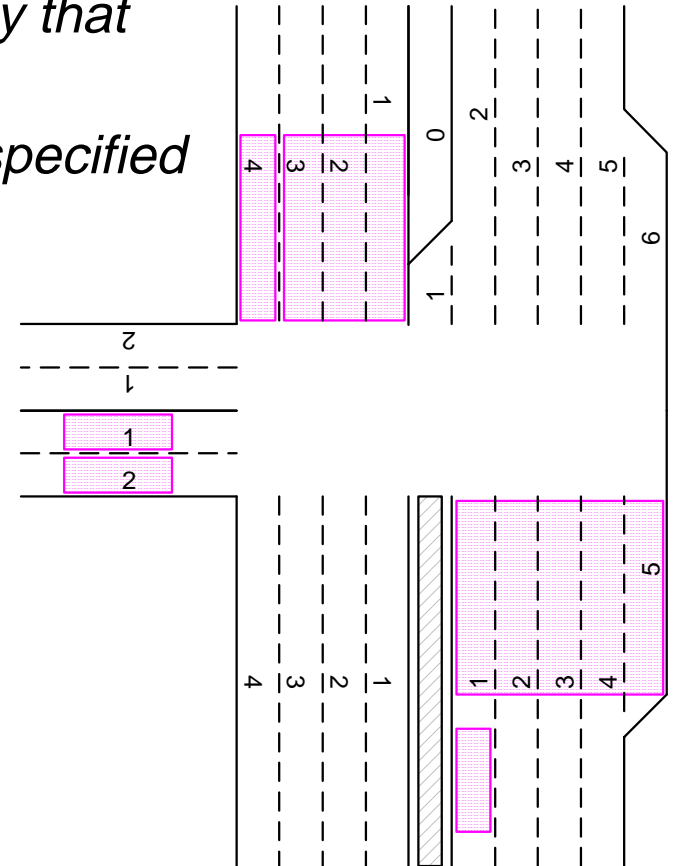
Signal Description

- *Turning movements at intersections are associated with each phase:*
 - *protected*
 - *unprotected*
 - *protected after stop*
- *One or more detectors are associated with each movement.*
- *Timing plans specify the lengths of phases:*
 - *initial green and extension*
 - *yellow*
 - *red clear*
- *Phase progression may be constrained.*
- *Signals have single or dual rings.*
- *Each control algorithm has a specific set of parameters.*



Detector Description

- Detectors record the presence or passage of vehicles.
- Detectors lie on a rectangle of roadway that may span multiple lanes.
- Detector efficiency and accuracy are specified parametrically:
 - An offset and noise may be applied to measurements of position, velocity, and acceleration.
 - A detector may . . .
 - miss a vehicle
 - count a vehicle twice
 - report a vehicle where none exists
 - A detector may fail altogether.
 - A failed detector may be repaired.
- Detectors need not sample the roadway every second—other sampling rates may be used.



Detector Response

- *Detectors provide a (possibly noisy) **time series** of vehicle detections:*
 - *position*
 - *velocity*
 - *acceleration*
- *Specific **algorithms interpret** this time series.*
- *The **first algorithm** implemented estimates*
 - *density*
 - *flow*
 - *speed**within the detection region.*

Control Algorithm B

- Consider each *phase*: $p \in P$
- Several through or turning vehicle *movements* may be possible during this phase: $m \in M^{(p)}$
- One or more *detectors* measure demand for each movement: $d \in D^{(p,m)}$
- Use the vehicle *density* and *flow* estimates from the detectors: $\rho^{(d)}$ and $q^{(d)}$.
- The *probability* of selecting phase p as the next phase is related to the demand for the movements in the phase:

$$\pi_p \propto \prod_{m \in M^{(p)}} \frac{1}{|D^{(p,m)}|} \sum_{d \in D^{(p,m)}} e^{\beta \frac{\rho^{(d)} + \rho_0}{q^{(d)} + q_0}}$$

where β , ρ_0 , and q_0 are parameters.

- A *newly-chosen phase* persists for its *initial green* time;
a *reselected phase* persists for its *green extension* time.




Choosing the Control Parameters

- *Three parameters for controller:*
 - *velocity factor: β*
 - *density factor: ρ_0*
 - *flow factor: q_0*
- *One parameter per detector per movement:*
 - *length: ℓ*
- *Two parameters per phase:*
 - *initial green: G*
 - *green extension as a fraction of initial green: γ*

⇒ *An a priori choice of parameters is difficult. Therefore, we design experiments to explore the parameter space.*

Intersection for Experiments

■ Twelve turning movements

- four left 
- four through 
- four right 

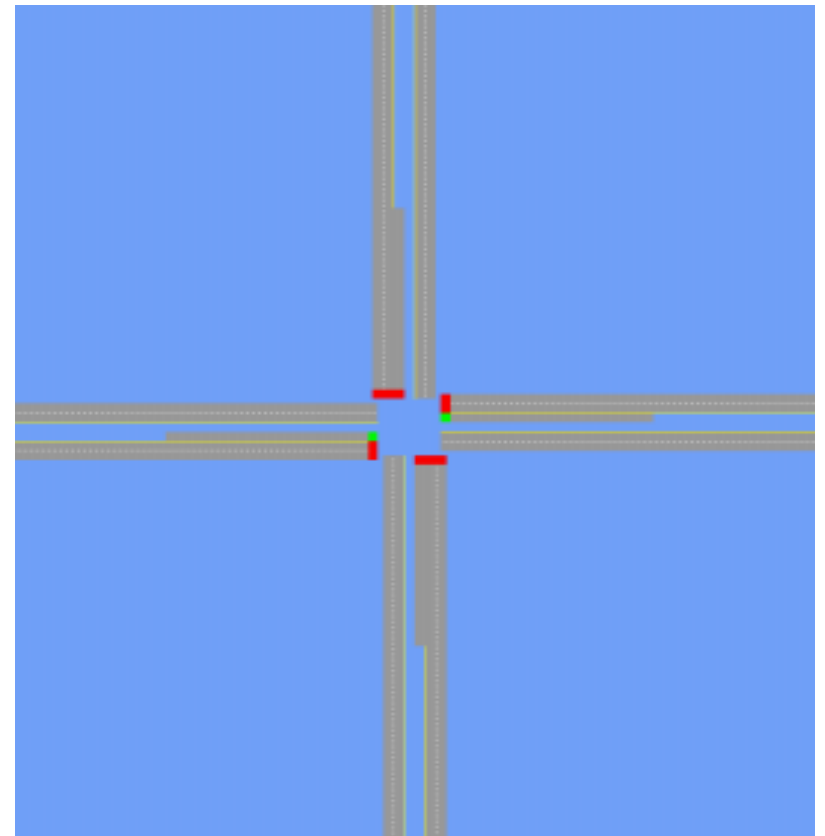
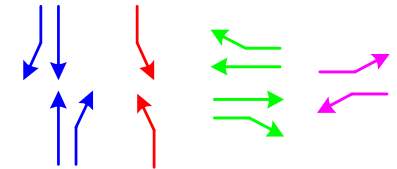
■ Demand represented by vehicle headways for twelve movements: $S = (S_1, \dots, S_{12})$

■ Nine control parameters: $P = (\beta, \rho_0, q_0, G_1, G_2, G_3, G_4, \gamma, \ell)$

■ Response represented by vehicle throughput for twelve movements: $C = (C_1, \dots, C_{12})$

■ Four phases

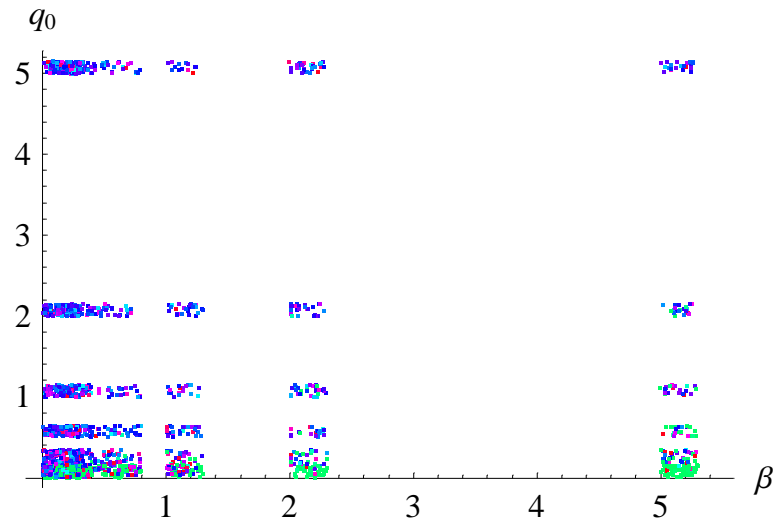
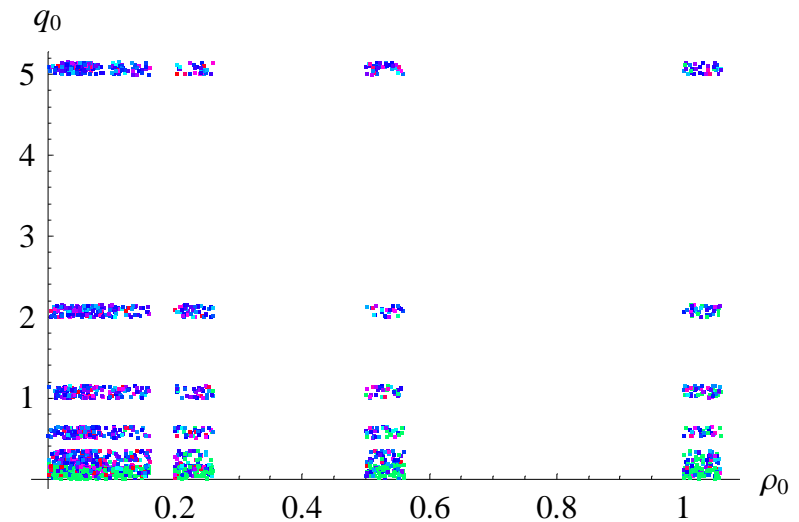
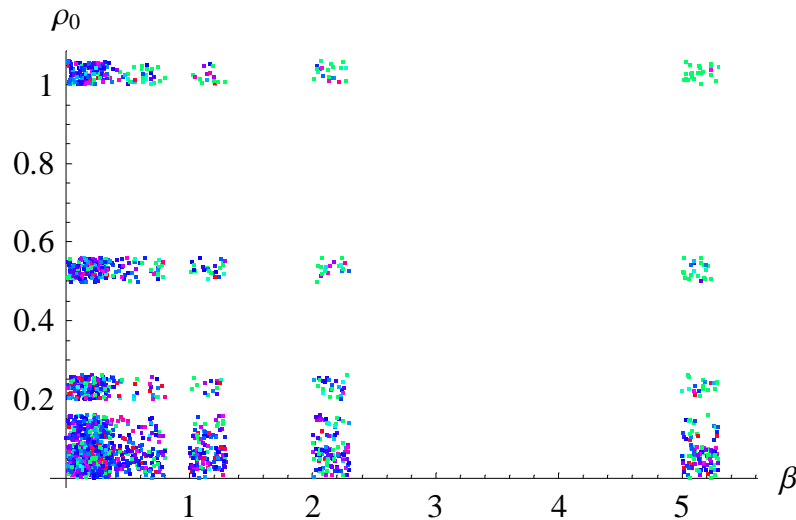
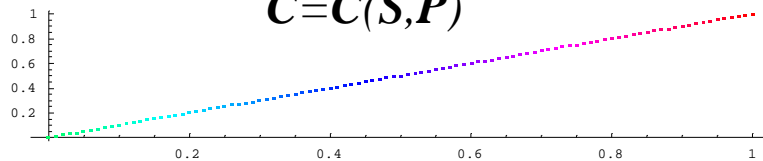
- two through
- two left



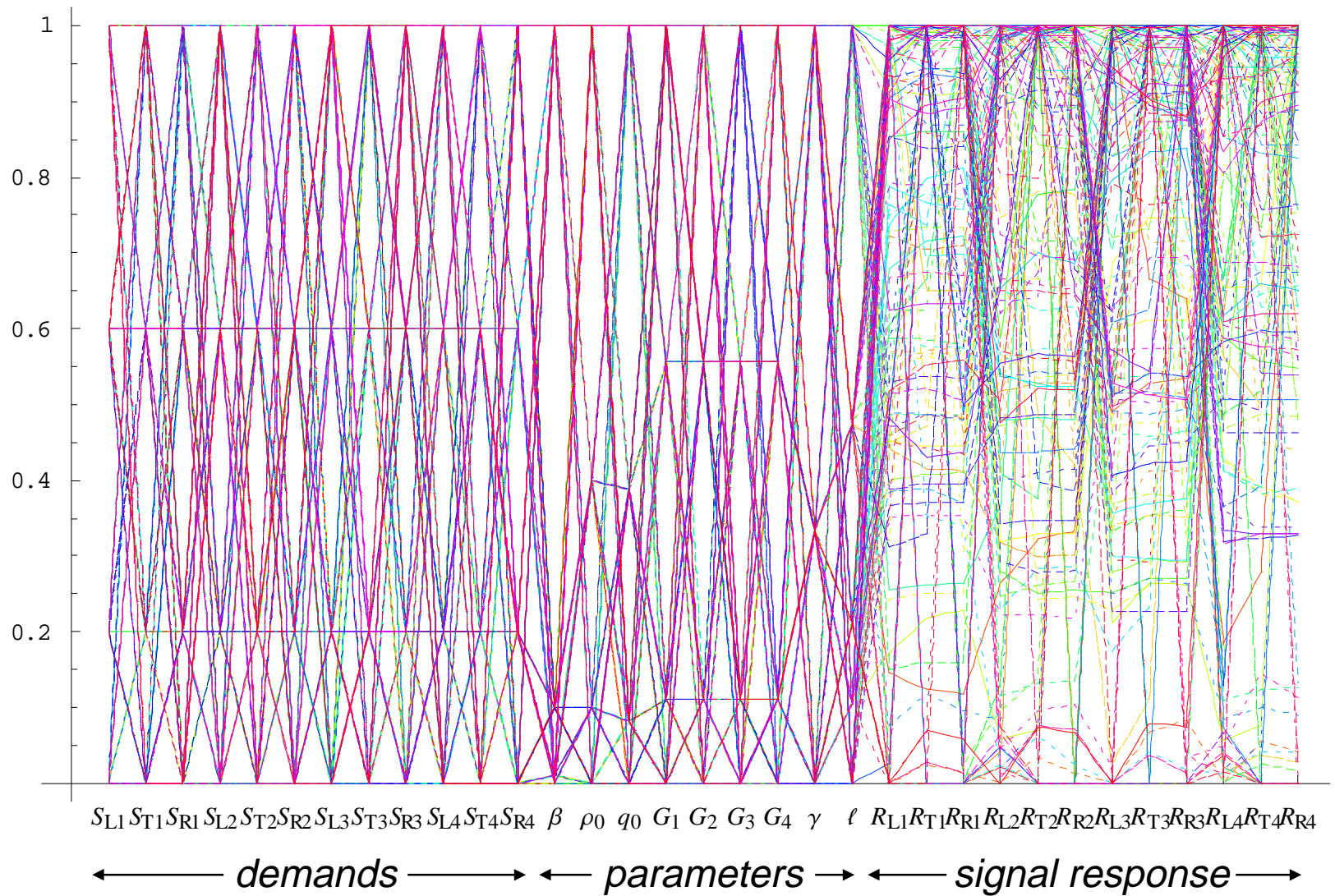
Signal Response Experiment

- use *Latin Hypercube* and *Fractional Factorial* experimental designs
- explore the relationship between demand, signal parameters, and throughput:

$$C = C(S, P)$$



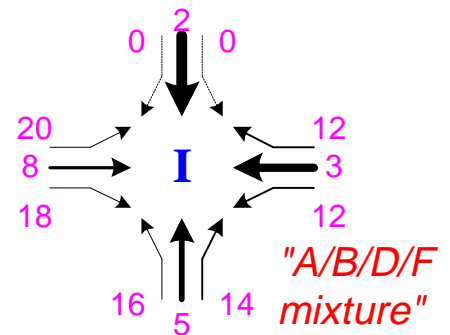
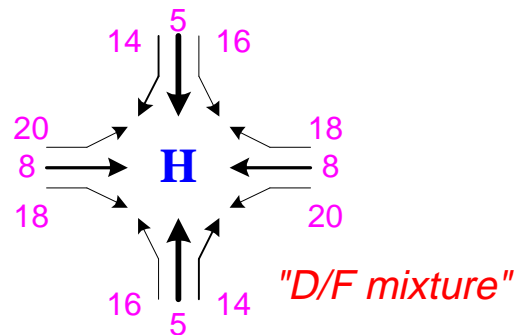
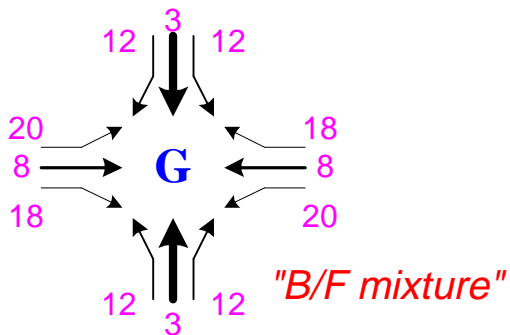
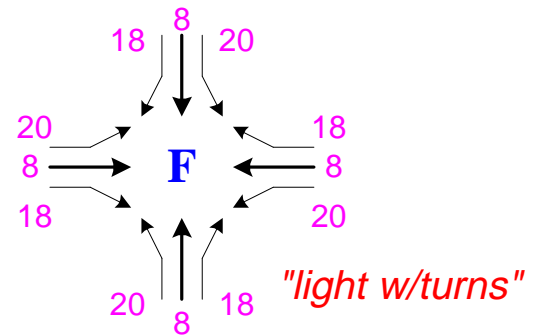
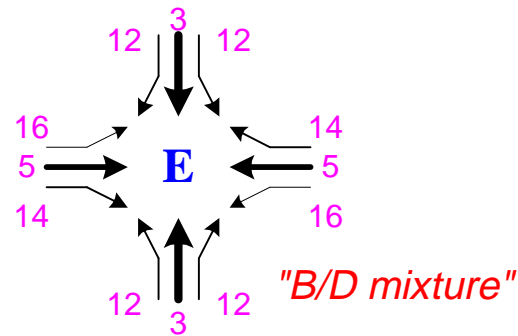
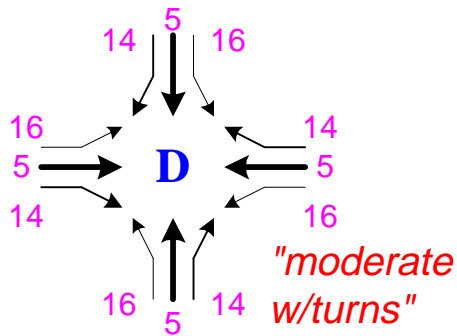
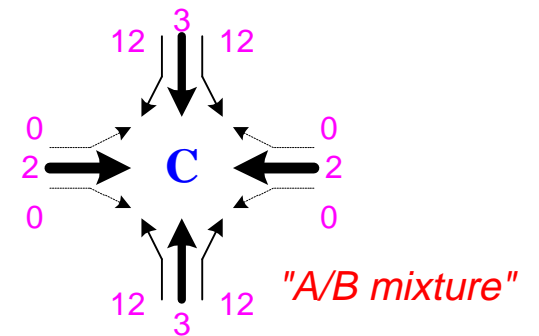
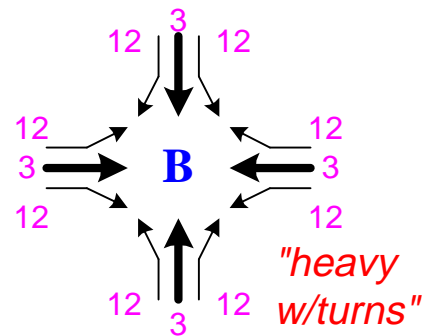
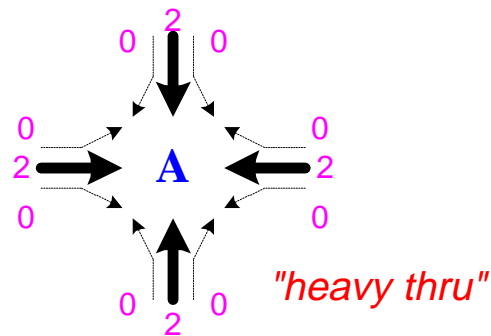
Signal Response Experiment (continued)



Parameter Optimization Experiment

- *consider nine demand vectors S representative of a variety of traffic conditions*
- *determine the pretimed signalization for each demand from the Traffic Control Handbook and the Highway Capacity Manual*
- *use Latin Hypercube and Fractional Factorial experimental designs to search the parameter space P of the actuated signal algorithm*
- *compare performance C of the actuated signals versus the standard pretimed signals*

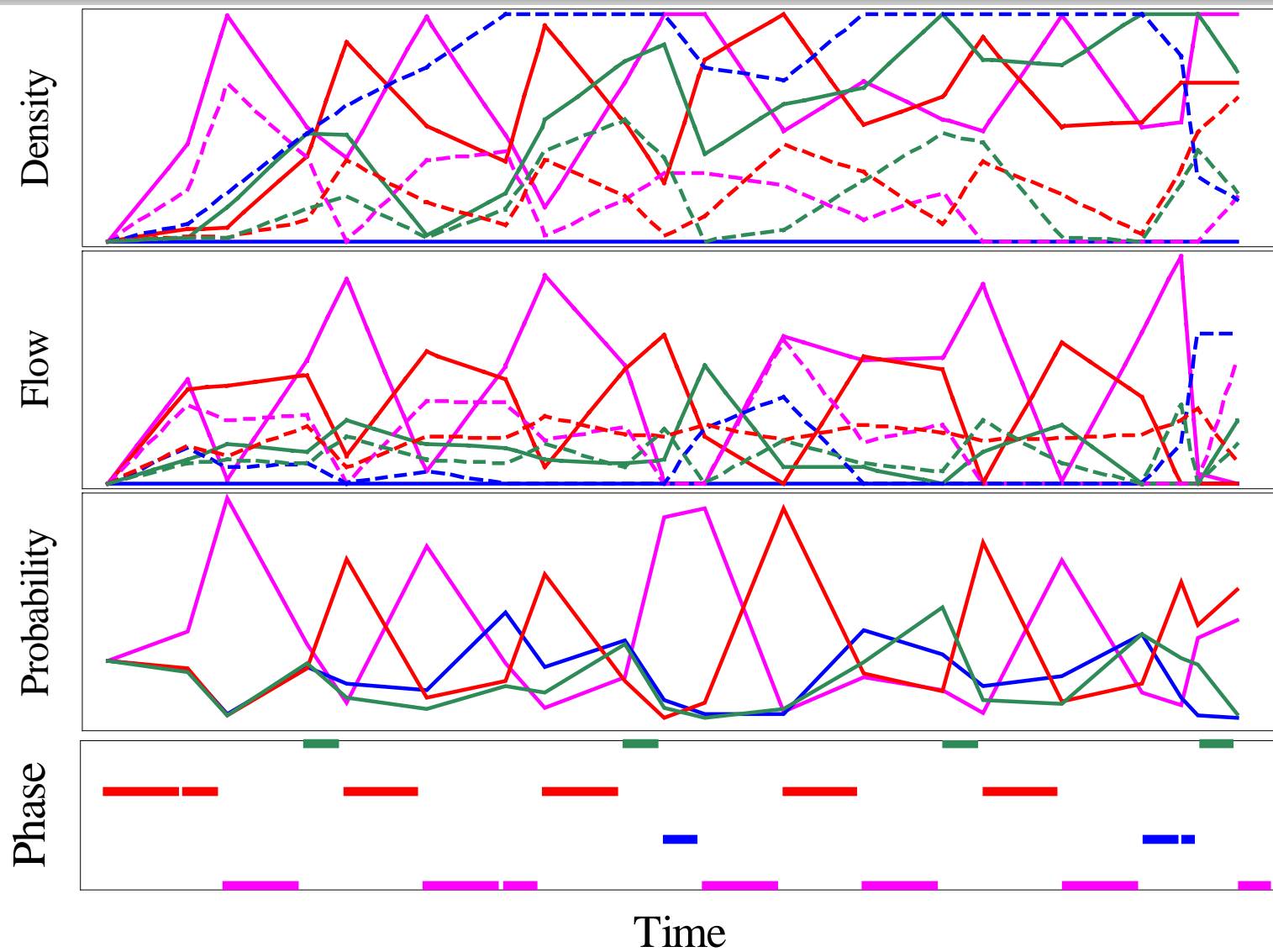
Vehicle Headway Patterns for Parameter Optimization



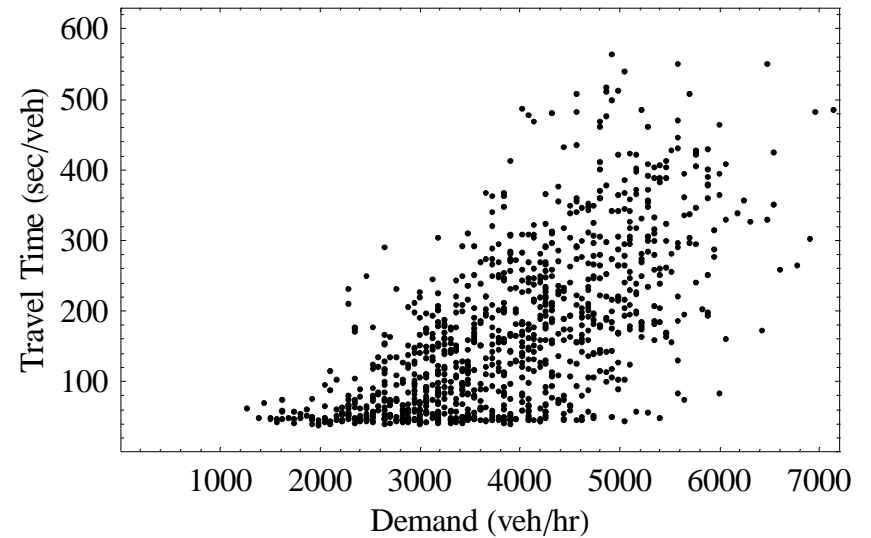
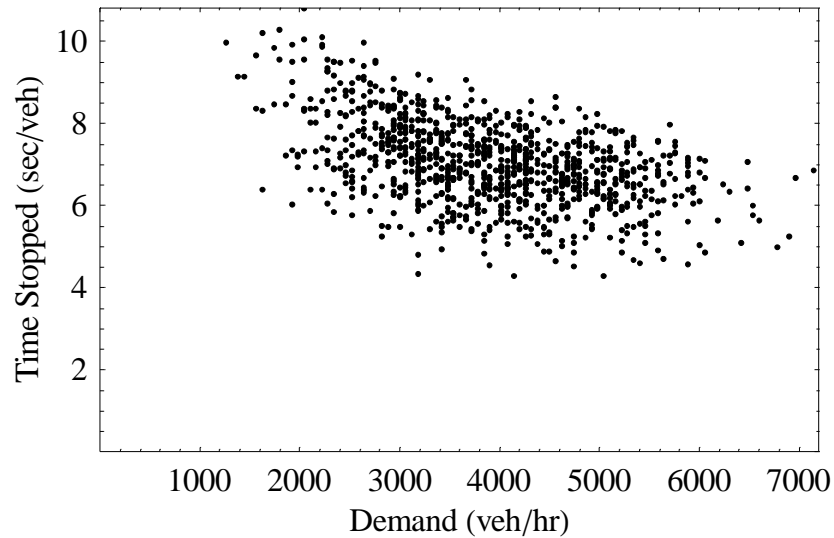
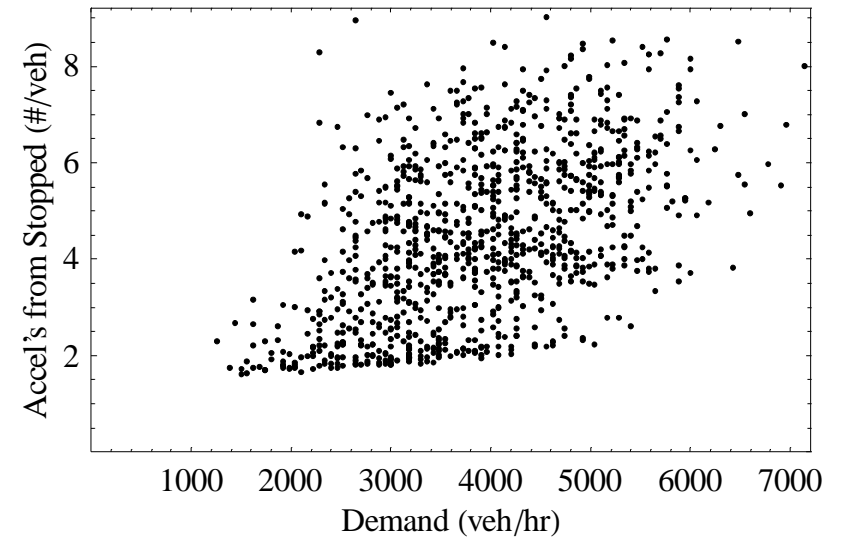
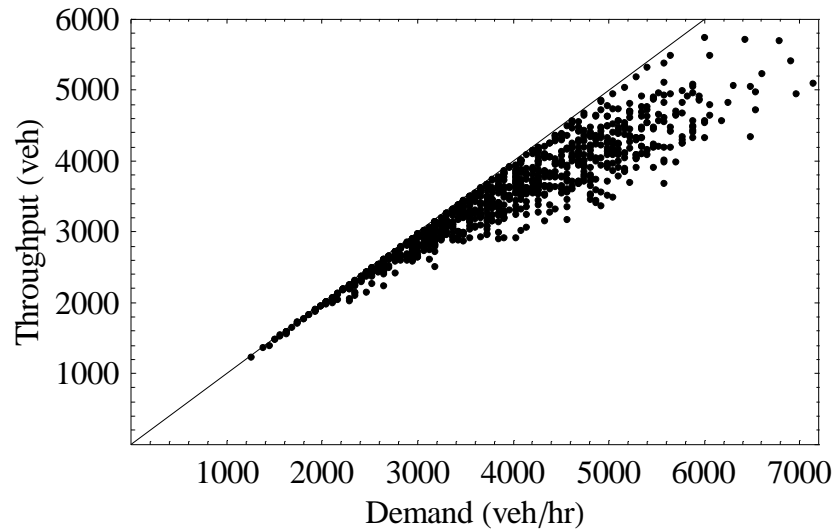
Results of Parameter Optimization Experiment

- *Simulated approximately 10,000 hours of traffic (required two days of computing).*
- *Optimal parameter set for actuated signal algorithm:*
 - *$\beta = 1.0$ meters per second*
 - *$\rho_0 = 0$ per meter*
 - *$q_0 = 0.1$ per second*
 - *$G_T = 20$ seconds*
 - *$G_L = 8$ seconds*
 - *$\gamma = 60\%$*
 - *$\ell = 37.5$ meters*
- *This **actuated signal outperforms** pretimed signals:*
 - ***1st place** for seven demand levels: B,C,D,E,F,G,H*
 - ***2nd place** for two demand levels: A, I (within 4% of best pretimed signal)*

Phase Progression for Demand Case “I”



Signal Response to Randomly-Varied Demand



Other Possible Performance Measures

■ *lane*

- *flow rate*
- *occupancy*
- *speed*
- *density*
- *headway*
- *queue length*

■ *vehicle*

- *stops*
- *seconds stopped*
- *time delay*
- *accelerations*

■ *other*

- *throughput*
- *platoon ratio*
- *progression*
- *unsatisfied demand*

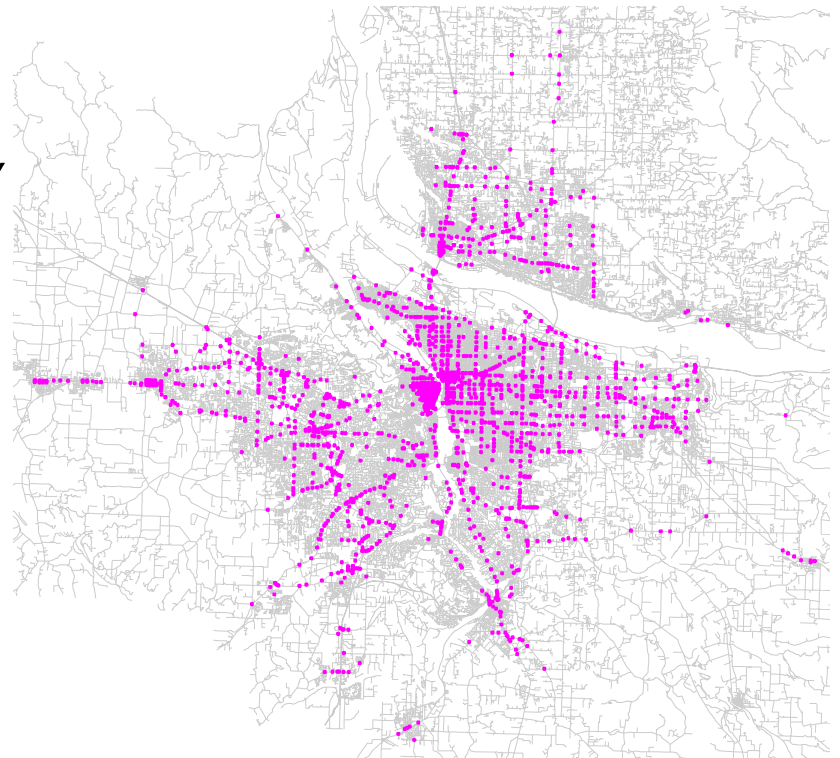
Applications

■ *advantages*

- *one set of parameters sufficient for a wide variety of traffic situations*
- *coordination between signals should emerge naturally*
- *fast (can simulate $\sim 10^5$ vehicle-seconds per CPU-second on 250 MHz Solaris CPUs)*

■ *studies*

- *Portland, Oregon case study*
 - *several thousand signals*
- *future ITS work*



Prospects

- *Continuing calibration studies:*
 - *refined heuristics for choosing parameters*
 - *optimization methodology*
 - *behavior at a variety of intersection types*
 - *study of larger networks*
 - *natural emergence of coordination over wide areas*
- *Automatic generation of controls on networks:*
 - *pattern recognition techniques*
- *Enhancing implementation:*
 - *more complex ring structures*
 - *algorithms for specific controllers*
 - *coordination of signals (i.e., wide-area control)*
 - *ITS technologies*